APPENDIX 8-5

EMBANKMENT TECHNICAL MEMORANDUM II

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

BLACK & VEATCH

TECHNICAL MEMORANDUM

South Florida Water Management District — B&V Project 141731
EAA Reservoir A-1 — B&V File:
Work Order No. 7 — First Issue: June 28, 2005
Last Updated: July 15, 2005

Task 7.1.1.2.2 Embankment Technical Memorandum II

To: Distribution

From: Kevin Lee, Denton Voss, Jim Touslee

1. INTRODUCTION

In October 2003, South Florida Water Management District (District) decided to pursue a "Dual Track" for the Everglades Agricultural Area (EAA) Reservoir project. While the multi-agency Project Delivery Team, lead by the Corps of Engineers, continues to develop the Project Implementation Report, the District is proceeding with the design of a reservoir (designated EAA Reservoir A-1 Project) located on land acquired through the Talisman exchange in the Everglades Agricultural Area.The purpose of the Project as defined in the CERP is to capture EAA Basin runoff and releases from Lake Okeechobee. The facilities will be designed to improve the timing of environmental water supply deliveries to STA 3/4 (Storm Water Treatment Area 3/4) and the WCA's (Wetland Conservation Areas), reduce Lake Okeechobee regulatory releases to the estuaries, meet agricultural irrigation demands, and increase flood protection within the EAA.

This Embankment Technical Memorandum II follows the Embankment Technical Memorandum under Work Order 2 (WO2) which was prepared prior to this memorandum. The Embankment Technical Memorandum under WO2 summarizes the characteristics of five reservoir embankment cross sections and discusses their merits in greater detail.

1.1 Objectives

[Since the issuance of this memorandum, additional embankment alternatives have been added for consideration. These additional alternatives will be discussed in detail in the BODR. Additionally, some modifications to the embankment alternatives herein are discussed in the BODR. Finally, it should be noted that wave run-up and wind set-up calculations as given in this memorandum cover the regular wave occurrence and not an irregular wave occurrence. Therefore, if an irregular wave did occur, some overtopping would be observed. The impact of this overtopping would most likely result in minimal erosion on the downstream side of the embankment crest. Detailed wave analysis is discussed in Appendix 5-14 of the BODR.]

The objectives of this Technical Memorandum are to:

- Summarize at least five embankment cases for which comparative costs were developed

- Discuss cost implications of various construction methods for construction of the five selected embankment cross sections
- Summarize comparative costs for each embankment alternative for EAA Reservoir A-1

This memorandum describes the cost impacts of each alternative. These cost impacts are to be used in conjunction with other considerations identified in the Embankment Technical Memorandum under WO2 to develop a final recommendation.

2. EMBANKMENT CONSTRUCTION

2.1 General

As discussed in the Embankment Technical Memorandum under WO2, five embankment sections were selected for comparison. These five embankments were selected based on differing optimization of on-site material and design components. An additional embankment design is included as an option along the south border and the south portion of the west border along STA 3/4 and the Holey Land Wildlife Management Area (Holey Land). Figures for the six selected embankments are attached to this memorandum in the Appendix.

Embankment Alternative Nos. 1 through 3 require similar, though not identical, construction techniques. For comparative cost purposes, it was assumed that all materials other than cement and geomembrane were obtained from either the excavation of an adjacent seepage canal, an internal borrow canal parallel and adjacent to the embankment, or from one of several centralized borrow areas located within the reservoir footprint. Use of the material from the canals will be maximized first. The seepage canals were assumed to be 15-ft deep with a 40-ft bottom width and side slopes of 2:1. Furthermore, it was assumed that the centralized borrow areas would be located near any crusher or batch plant operations and arranged such that the hauling distance from excavation to placement would be approximately 2 miles or less.

Notable material zones in Embankment Alternatives 1 through 3 include:

- a rockfill shoulder to add strength and stability
- a core of select fill or a core of random fill with a maximum particle size of 6-inches to provide a zone of low permeability
- a transition material placed next to select fill sections to prevent migration of the select fill
- filter and drain layers to control the line of seepage through the embankment,
- roller compacted concrete (RCC) on the interior of the embankment to provide erosion protection due to wave action
- a layer of topsoil to provide for seeding for an aesthetic exterior slope

The remainder of the zones, including fill above the normal water level (NWL) plus the probable maximum precipitation (PMP) level, will typically be a random fill material. Cost of random fill material was assumed to be lower than the other fill material as it requires no special handling or processing and can be obtained from excavated material not suitable for one of the other fill types.

Embankment Alternative Nos. 4 and 5 employ RCC for the entire cross section. The RCC provides strength, stability, and erosion protection for the entire embankment. Comparative costs were developed for the RCC sections based on two different placement methods. The first type covers formed, vertical portions, and the second covers the mass placement and compaction of the core of the sections. These placement methods were separated due to the differing equipment and crews that would need to be employed for each.

Embankment Alternative No. 6 applies only to that portion of the embankment adjacent to the STA 3/4 supply canal in that it utilizes the existing north levee of the STA 3/4 supply canal. For this alternative, the embankment is placed directly above the existing seepage canal. As illustrated in Embankment Alternative No. 6 in the Appendix, the shoulder of the existing perimeter canal is used as a portion of the reservoir embankment, and the embankment is considered homogeneous compared to the other earthen embankment alternatives. The advantages and disadvantages of this option are discussed further in the Embankment Technical Memorandum under WO2.

2.2 Earthen Embankments, Alternatives 1 through 3

2.2.1 Rockfill Shoulder

Material for the rockfill shoulder will be taken from the layer of caprock, the top of which is found at approximately EL. 8.0. It was assumed that this layer would be excavated from the seepage canal excavation zone and the adjacent internal canal as needed. The material would then be hauled to the embankment location and stockpiled either on the interior bench between the embankment and the internal canal or in the location of its final placement. The latter stockpile location minimizes any additional bulk handling of rockfill during construction of the embankment and thereby reduces costs. This savings is dependent on the final construction schedule and contract details, and therefore is not reflected in the comparative costs included herein. This zone is found only in Embankment Alternative No. 1.

2.2.2 Select Fill Core

Material excavated from the Fort Thompson layer immediately below the caprock will serve as the source for select fill. The performance of this material with regard to permeability is described in detail in the Embankment Technical Memorandum under WO2. Of importance to the cost of this material, is the presence of 2 layers of limestone within the Fort Thompson layers. These limestone layers were noted to be of a low enough strength to be removed with an excavator, but additional handling will be required to remove these limestone portions from the select fill material before placement in the embankment. This serves to increase the cost of the select fill material placement. Observed strength values can be obtained in the Test Cell Construction and Seepage Monitoring Report.

2.2.3 Transition Material

The gradation necessary for transition material depends on the zones between which the material is intended to transition. This can cause transition material to vary between a certain gradation of rock and a given type of soil. For the purpose of cost comparison, it was assumed that transition material would consist of a material obtained from excavated caprock, which would then be crushed to remove larger sized particles. It was further assumed that the material would be obtained from one of the centralized borrow areas rather than the internal borrow canal in order to avoid frequent relocation of the crusher operations.

2.2.4 Filter and Drain Layers

Filter and drain layers are used to control seepage through the embankment. Filter and drain materials are obtained by crushing, screening, and washing excavated caprock to the specified gradation. Construction efforts for all these processes are included in the cost of filter and drain material. Since the preparation of the filter and drain materials require the use of a crusher, the source of materials was assumed to be one of the centralized borrow areas. The crushing and screening operation is discussed in more detail in the Test Cell Construction and Seepage Monitoring Report.

2.2.5 Roller Compacted Concrete (RCC)

RCC will be placed on the interior slope to provide erosion protection. Two placement types will be used for this. The lower section will be a flat faced layer laid on the slope of the embankment. This will extend to the NWL + PMP level. Above that, the section will consist of stepped RCC plates stacked and staggered to the top of the embankment. This construction method is more costly than the flat faced layer, especially since it is not a continuous effort. However, it provides a greater protection in the zone where higher wave energy is most likely to occur with intense storm or hurricane events and reduces wave run-up.

2.2.6 Topsoil

In order to add aesthetic appeal to the embankment alternatives, a layer of topsoil will be added to the exterior face for seeding. This material will be obtained from peat removed from the embankment location. The peat will be stockpiled adjacent to the location of the exterior toe of slope to reduce handling and cost.

2.3 Roller Compacted Concrete Embankments, Alternatives 4 and 5

2.3.1 General

A homogeneous RCC cross section offers the benefit of one material supplying strength, stability, and erosion protection for the embankment. However, as shown in the Cost Table found in Section 5.1 of this memorandum, RCC sections appear to be more costly than earthen embankments. In order to produce RCC, it was assumed that a batch plant would be located on site. Material excavated from the seepage canal and the centralized borrow areas would be transported to the batch plant, and mixed with cement. The material would then be transported to the embankment location where it would be placed in 12” or less lifts. Each lift would need compaction and surface preparation before the next lift is placed. Additional cost was added for vertical formed surfaces found on the inside slope of Alternative No. 4 and the stepped surfaces of both Alternative Nos. 4 and 5. These additional construction efforts add to the cost of the Alternatives, resulting in higher costs per total amount of placed material than the earthen embankments.

3. DESCRIPTION OF CASES

3.1 General

Dimensions for the selection of embankment cases included in this cost comparison were derived from a number of sources. Acceler8 Design Criteria Team's Design Criteria Memorandum: DC-4, 'Minimum Dimensions of Dams and Embankments', dated March 21, 2005, was used as reference for crest width and side slopes. From this memorandum a crest width of 14-ft was established, and side slopes of 3H:1V were selected for Embankment Alternative Nos. 1 through 3. Embankment Alternative No. 4 was derived from a section developed by the Jacksonville District of the U.S. Army Corps of Engineers, and a crest width of 14-ft was maintained for this section. Since seeding, and therefore mowing, is not necessary with a homogeneous RCC section, a 3H:1V side slope on the exterior side of the embankment would not be necessary. Cases are summarized in Table 1.

3.2 Water Levels, Wave Run-up, Wind Set-up, and Embankment Heights

Wave run-up and wind set-up analyses were completed under Work Order 3 (WO3). Dimensions for wave run-up and wind set-up were determined by varying such factors as water depth, fetch distance, and wind and rain conditions. Several sub-cases were analyzed using various internal side slopes and storm events. Internal side slopes were varied from 3H:1V for the earthen embankments to vertical-faced for the RCC sections. Additionally, two storm events were considered: a wind speed of 158 mph with no additional precipitation, and a wind speed of 104 mph with the PMP occurring after three dry days following a storm of 30% of the PMP. Wave run-up and wind set-up were calculated and added to the water depth, depth of peat, and any precipitation to determine the total embankment height for each of these sub-cases. Finally, the sub-case resulting in the most conservative (greatest) height was selected for cost comparison. The means and methods of this analysis are described in further detail in the technical memoranda under WO3. The case heights are summarized in Table 2. Governing heights are shown in bold print for each case.

3.3 Breakwaters and Embankment Heights

In addition to varied water depth, wind, and rain conditions, the presence of breakwaters was analyzed for their impact on the cost of embankment sections. From the results of wave run-up and wind set-up modeling performed under Work Order No. 3, it was determined that the inclusion of a full perimeter breakwater would decrease the overall embankment height, but the reduction in embankment material was significantly less than the increase in material necessary to construct the breakwaters. In fact, the amount of total material required for a shorter embankment with a breakwater is greater than a taller embankment without a breakwater in all cases. This is illustrated in Table 3 for the governing height condition as explained in section 4.2 of this memorandum.

In addition to increased cost associated with additional material for breakwaters, material feasible for the construction of the breakwater is in short supply. This is discussed further in the Test Cell Construction and Seepage Monitoring Report. Therefore, the overall embankment cost would actually be greater if breakwaters were included due to increased material and construction feasibility.

4. RESULTS

4.1 Cost Comparison Summary

Cost comparison values for each embankment alternative were developed based on the material handling and processing procedures discussed previously and the additional assumptions listed herein. These values were derived either from RS Means 2005 Construction Cost Data (Means) or from quotes from contractors. Labor wage rates were based on Means with base rate plus benefits and fringes. Equipment rental rates were based on monthly rental and operating costs (fuel, oil, lube, etc.); no labor costs were included in the equipment rental rates.

These values are presented for comparison only and do not include the cost of all construction activities necessary for embankment construction and similar to all variations of embankment cross sections. The following is a list of major cost items that were not included for cost comparison.

- Excavation of material from the seepage canal (excavation of material from the internal borrow canal and the centralized borrow areas were included in the comparative costs)
- Site clearing of peat from the bench area located between the embankment and the seepage canal and from the centralized borrow areas
- Construction of an access/inspection road around the outside of the embankment
- Post-construction development of any wetland area located between the access/inspection and the seepage canal
- Contingency and project reserves

The results of the cost comparison are given in Table 4. All costs assume no breakwater construction.

4.2 Discussion of Costs

As discussed in the Embankment Technical Memorandum under WO2, Embankment Alternative No. 1 was developed to minimize material handling. Therefore, its cost is lower than all other earthen embankment costs. Embankment Alternative No. 5 has a much higher cost than Alternative No. 4 due mainly to the labor intensity of compacting the RCC as well as the much larger volume of RCC. All cost differences should be considered only in light of the performance and suitability of each embankment design as discussed in the Embankment Technical Memorandum under WO2.

If Embankment Alternative No. 6 is selected along STA 3/4 and the Holey Land, the remaining portion of the reservoir perimeter must be constructed with earthen embankment. This would result in a lower total cost as Alternative No. 6 has the lowest comparable cost. If one alternative is selected for the entire perimeter, the embankment along STA 3/4 and the Holey Land would have to be set back, thus reducing the amount of total storage, and no cost saving would occur.

The cost differential between the 12-ft water depth and the 15-ft water depth was found to vary between 10% and 20%. The Reservoir Configuration Memorandum discusses additional storage volume for 15-ft water depth compared to that of the 12-ft water depth. Additionally, it gives a percentage increase in volume of embankment for the two water depths. This increase in storage volume is proportionally greater than the increase in embankment cost for the change in water depth. This is mainly due to the fact that the increased material volume is predominately that of random fill, which is one of the least expensive materials to place. However, further analysis would be required to determine an optimum water depth that provides the least amount of cost per acre-ft of storage.

5. REFERENCES

Embankment Technical Memorandum (Work Order No. 2)

Test Cell Construction and Seepage Monitoring Report

TABLES

Table 1 - Definition of Cases:
Case 1 - 12-ft water depth with no breakwater
Case 2 - 15-ft water depth with no breakwater
Case 3 - 12-ft water depth with a 20-ft tall perimeter breakwater
Case 4 - 15-ft water depth with a 23-ft tall perimeter breakwater

Table 2 - Embankment Heights (Results of Wave Run-up and Wind Set-up Analysis)

	Water Depth (ft)	Peat Depth (ft)	Wind Speed (mph)	PMP (plus storm) (ft)	Interior Slope --	Wave Run-up (ft)	Wind Set-up (ft)	Total Height (ft)
Case 1a	12	2	158	0	3:1	6.4	7.4	**27.8**
Case 1b	12	2	104	5.85	3:1	5.8	2	27.7
Case 1c	12	2	158	0	Vertical	8.8	7.4	**30.2**
Case 1d	12	2	104	5.85	Vertical	7.8	2	29.7
Case 2a	15	2	158	0	3:1	7.2	6	30.2
Case 2b	15	2	104	5.85	3:1	6.2	1.7	**30.8**
Case 2c	15	2	158	0	Vertical	10.3	6	**33.3**
Case 2d	15	2	104	5.85	Vertical	8.3	1.7	32.9
Case 3a	12	2	158	0	3:1	2.9	3.5	20.4
Case 3b	12	2	104	5.85	3:1	2.5	1.2	**23.6**
Case 3c	12	2	158	0	Vertical	5.7	3.6	23.3
Case 3d	12	2	104	5.85	Vertical	5.3	1.2	**26.4**
Case 4a	15	2	158	0	3:1	2.9	3.5	23.4
Case 4b	15	2	104	5.85	3:1	2.5	1.2	**26.6**
Case 4c	15	2	158	0	Vertical	5.7	3.6	26.3
Case 4d	15	2	104	5.85	Vertical	5.3	1.2	**29.4**

	No Breakwater		Breakwater	
Table 3 - Embankment Total Quantities:	**Case 1, 12' Depth**	**Case 2, 15' Depth**	**Case 3, 12' Depth**	**Case 4, 15' Depth**
Alt #1 - Inclined Internal Core	100	121	112	141
Alt #2 - Embankment with Geomembrane	101	122	113	142
Alt #3 - Embankment with Central Core	101	121	113	142
Alt #4 - RCC (Original USACE Design)	38	42	72	87
Alt #5 - RCC (Alternate)	76	89	100	122
Alt #6 - Southern Embankment (along STA 3/4)	91	112	103	133
** All quantities are in cubic yards of material per one lineal foot of total embankment (yd^3/ft)				

Table 4 - Comparison Costs per Linear Ft. of Embankment

Case	Alt No. 1	Alt No. 2	Alt No. 3	Alt No. 4	Alt No.5	Alt No.6
12-ft	$2,197	$2,512	$3,154	$2,437	$4,875	$1,779
15-ft	$2,622	$2,928	$3,644	$2,691	$5,728	$2,132

FIGURES

Figure 1 **Embankment Alternative 1**

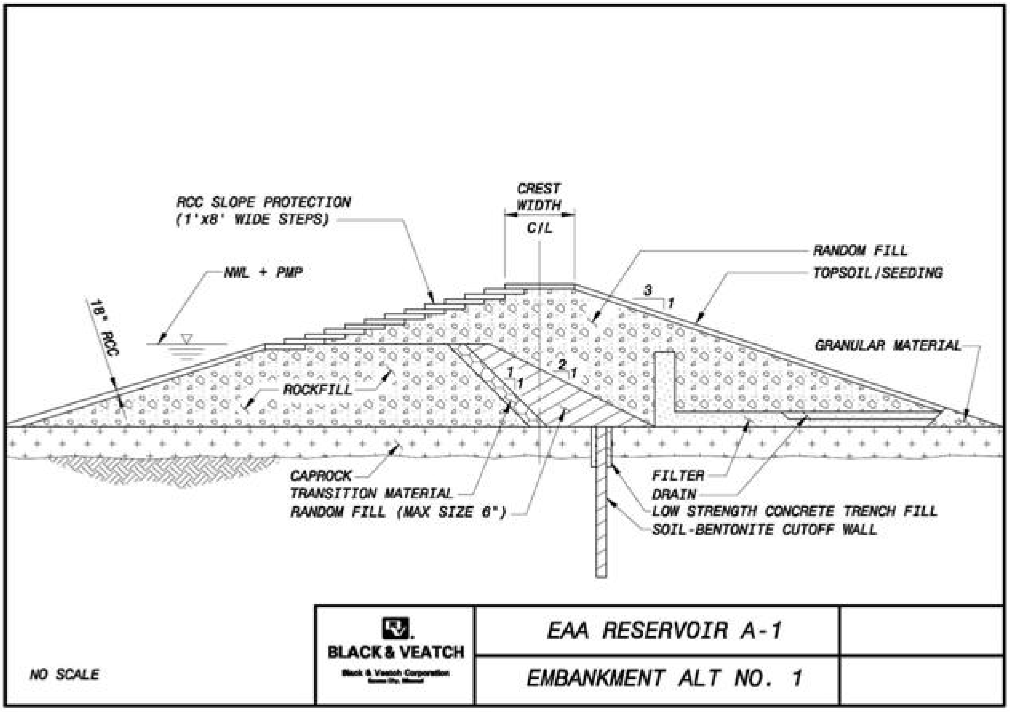

Figure 2 Embankment Alternative 2

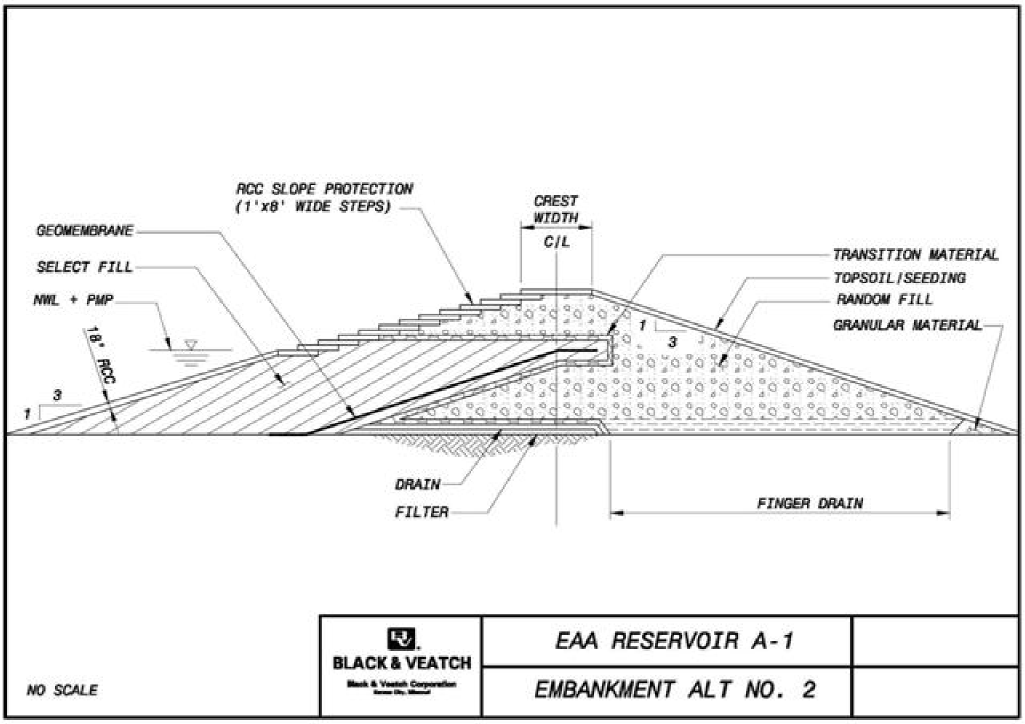

Figure 3 Embankment Alternative 3

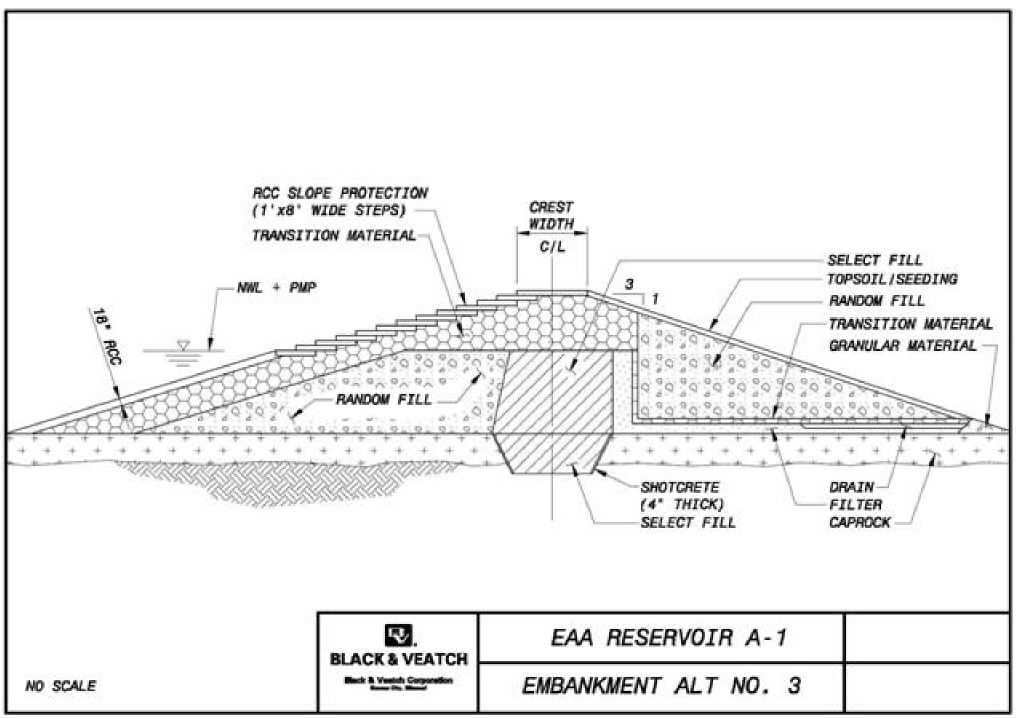

Figure 4 Embankment Alternative 4

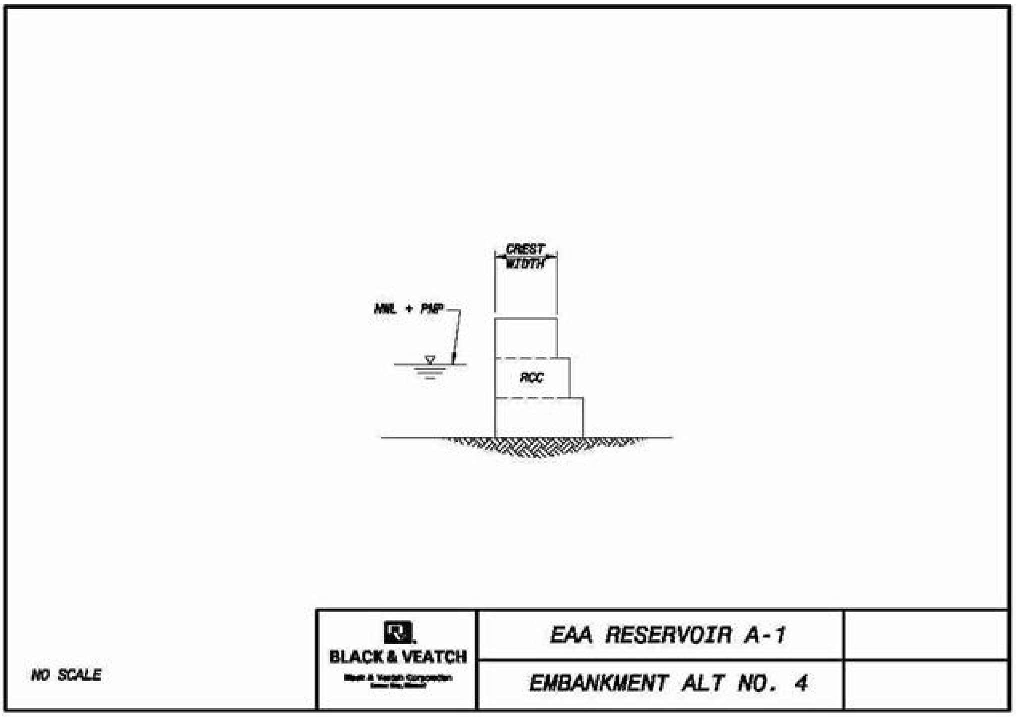

Figure 5 Embankment Alternative 5

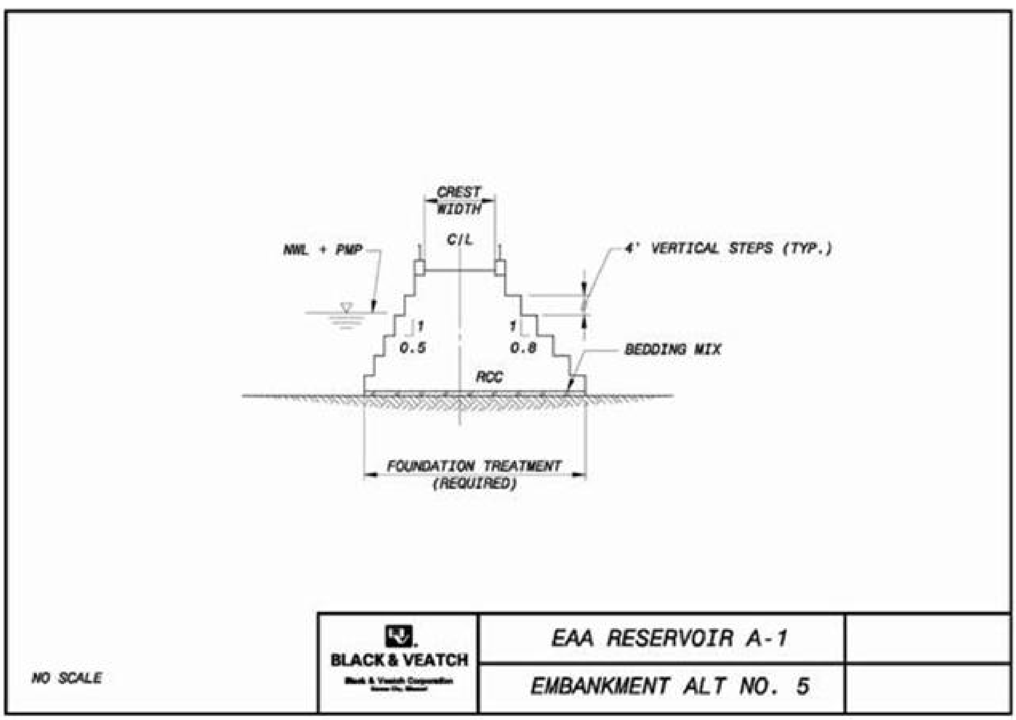

Figure 6 Embankment Alternative 6